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IMPLICATIONS OF PRIVACY NEEDS AND INTERPERSONAL DISTANCING MECHANISMS FOR SPACE STATION DESIGN

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ABSTRACT

The present paper reviews the literature on privacy needs, personal space, interpersonal distancing, and crowding, with special reference to spaceflight and spaceflight-analagous conditions; proposes a quantitative model for understanding privacy, interpersonal distancing, and performance; and describes the implications for Space Station design.

EXECUTIVE SUMMARY

Privacy needs, or people's needs to control the degree of interpersonal contact that they have with one another, and interpersonal distancing behavior, which serves to regulate interpersonal contact, are important performance-related variables. Drawing on general literature on privacy and interpersonal distancing and on specialized literature on life aboard spacecraft and in spacecraft-analagous environments, the present paper proposes a quantitative model for understanding privacy, interpersonal distancing, and performance, and discusses the practical implications for Space Station design.

People need to control the degree of contact that they have with one another in order to best perform various work, recreational, and self-maintenance tasks. Reduced interpersonal contact aids performance of tasks which are structured for individual action, helps reduce physiological activation or arousal, increases control over the images that are projected to other people, and makes it possible for small groups of people to interact with one another free from surveillance of the larger group. Increased contact with others facilitates the performance of tasks that are structured for group action, increases arousal, increases certain kinds of informational inputs, and helps reduce fear or anxiety. Space Station astronauts will have to perform an array of work, recreational, and self-maintenance tasks which will sometimes require them to restrict and at other times to expand contact with one another.

Interpersonal distancing mechanisms help people regulate interpersonal contact. Person-environment mechanisms involve the use of space and architecture (moving out of an area, closing doors and so forth). Psychological mechanisms involve flight responses (social withdrawal, mentally "tuning the other person out," and so forth) and fight responses (behaviors which encourage avoidance on the part of potential intruders). Social normative mechanisms involve group rules that specify appropriate degrees of contact.

Isolation, confinement, and other spaceflight conditions at once augment people's needs to regulate interpersonal contact and compromise the effectiveness of interpersonal distancing mechanisms. Aboard spacecraft, volume and weight restrictions limit the amount of physical distance that can be sustained, and also the availability of walls and other architectural barriers. Physical distancing is further complicated by the conditions of weightlessness. Normal fight and flight tendencies tend to be suppressed because they hint of maladjustment. Nonverbal and verbal communication, which provide underpinnings for many interpersonal distancing attempts, may be degraded in space. Since spacecraft environments are relatively new, there has not been much time for social norms to develop.

Loneliness occurs when the achieved level of contact falls below the desired level of contact, and crowding exists when the achieved level of crowding surpasses the mark. Both loneliness and crowding can pose problems for astronauts, but because of such considerations as highly limited interior space and surveillance by external monitors, crowding is considered the greater threat.

Crowding depends, in part, on the number of people per unit space. Perceptual and judgmental factors determine whether or not a certain level of social density is experienced as crowding. If an environment is defined as crowded, the occupants initiate interpersonal distancing attempts which are intended to reduce the crowding. If these attempts prove ineffective, then crowding is likely to have four kinds of adverse effects. First, there are psychophysiological effects including increased heart rate, heightened blood pressure, increased palmar sweat, and the secretion of stress-related substances into the bloodstream and urine. Second, there are psychological effects which include decreased ability to focus or concentrate, motivational decline, anger and depression, stubbornness, and negativistic attitudes. Third, there are social effects which include withdrawal, irritability, and social conflict. Fourth, there are adverse performance effects which are likely to be severe when the task involves a complex sequence of cognitive and motor activities, and when different performers are competing for the same space, tools, supplies, and other resources.

The proposed model defines a situation as consisting of an environment, or setting in which human activity takes place, and a task, which is goal-directed activity in any sphere of endeavor. The model focuses on interpersonal contact, which can occur along one or more of four contact dimensions: visual, auditory, olfactory, and tactile.

Environmental potentials refer to the degree or degrees of interpersonal contact that an environment affords its users; task requirements refer to the degree or degrees of interpersonal contact required by a task. Environmental potentials and task requirements can be expressed in terms of momentary values, average values or setpoints , and ranges. The model is additive, in that it involves summing across pairs of crewmembers, contact dimensions, and time. However, the model also permits separate analyses of subsets of crewmembers and subsets of contact dimensions.

Performance is best when the type and level of contact afforded by the environment aligns with the type and level of contact required by the task. Situational privacy refers to the degree of alignment between the environment and the task. Situational discrepancy refers to the degree of misalignment between the environment and task.

The algebraic difference between the environmental potential and task requirement constitutes the situational discrepancy, and the absolute value of the situational discrepancy is inversely related to performance. However, the relationship between situational discrepancy and performance is not necessarily monotonic. Minor discrepancies that fall within a range of acceptability are inconsequential. Moderate discrepancies that fall within a range of adjustability have a passing effect on performance. Some time may be lost on interpersonal distancing, but since the appropriate level of contact is attainable, the task does get done. Large discrepancies that arise when a task requires a level of social contact that falls outside of the range offered by the environment pose serious problems. In this case workers must either abandon the task, leave the environment, restructure the task, or restructure the environment. Computations of situational discrepancies can be based on momentary potentials, set points, and/or ranges.

The model suggests that when the social opportunities present in the environment and the social requirements of a task are aligned, performance will benefit. To achieve this, the environment can be pre-engineered to meet the task requirements ; the task can be structured to meet the social potential of the environment; or environments can be constructed in such a way as to provide users with a wide array of alternatives and options. Under this last scenario, the environment's users can behaviorally choose the level of contact that is most appropriate for the task. Given the constraints of spaceflight, this third option offers certain advantages. The key is a flexibile, definable, and redefinable interior environment that provides Space Station occupants with ample opportunities to meet their needs for solitude, limited social interaction, and open group activity.

Forty-nine recommendations are offered which fall into five general categories: room and furnishing arrangements; the maximization of actual and perceived interior space; the creative use of real and illusory barriers; the use of distractors that provide socially acceptable alternatives to interaction; and miscellaneous. The underlying theme is that large areas and a multitude of walls and doors are not required to accommodate an array of privacy needs. The careful planning of "hard" architectural features (interior dimensions, walls, doors, etc.); the use of lightweight or "soft" features (screens, movable partitions, and so forth); the creative use of decor variables such as color and light; the availability of perceptual diversions, and the recognition of possibilities in such areas as personnel selection, crew training, and social organization can promote a wide range of privacy options despite the Space Station's volumetric limitations.

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INTRODUCTION

Privacy needs, or needs to regulate interpersonal contact, and interpersonal distancing mechanisms which help provide such regulation, are common in all cultures. Isolation, confinement, and other conditions associated with spaceflight may at once accentuate privacy needs and limit the availability of certain common interpersonal distancing mechanisms. Under some conditions, prolonged frustration of privacy needs can encourage psychological withdrawal and other dysfunctional coping responses and directly or indirectly undermine performance. A thorough understanding of privacy needs and interpersonal distancing mechanisms will gain importance as space missions involve increasing numbers of astronauts aloft for increasing periods of time (Berry, 1973; Bluth, 1980, 1981, 1982; Boeing, 1983a, 1983b; Cheston & Winter, 1980; Connors, Harrison & Akins, 1985; Douglas, 1984; Harrison & Connors, 1984, 1985; Helmreich, 1983; Helmreich, Wilhelm & Runge, 1980; Kanas & Fedderson, 1971; A. Oberg, 1985; J. Oberg, 1981; Oberg & Oberg, in press; Sieber, 1980; Stuster, 1984).

Aims

The present paper discusses the effects of varying degrees of social contact on psychological well-being and task performance, and traces the implications for Space Station design. More specifically, there are three aims as follows:

1. exposition of current theory and research on privacy needs, personal space, interpersonal distancing, loneliness, and crowding, with special reference to spaceflight and spaceflight-analagous conditions;

2. initiation of a quantitative model for understanding privacy, interpersonal distancing, loneliness, and crowding;

3. assessment of the implications of the literature review and the model for Space Station design.

Methods

This paper represents a literature review and synthesis. The primary method for locating the appropriate literature was through computer searches of the Psychological Abstracts. During April and May 1985, the primary searches were performed featuring crowding, personal space, and privacy as descriptors. The results of these searches have been enhanced by additional Psychological Abstracts searches on behavioral topics related to spaceflight and spaceflight-analagous environments, and by supplementary searches of the National Institute of Health abstracts and the Sociological Abstracts. In addition, strenuous attempts were made to locate pertinent articles not covered by these computerized data bases.

Two assumptions guided the preparation of this manuscript. First, it was assumed that broad trends and reliable findings are more important than isolated results. Second, it was assumed that models which stress the functional relationships among observable variables are of greater value for planning the Space Station than are models which dote upon theoretical constructs. In other words, when it has been necessary to balance the academic and the practical, more weight has been assigned to the practical.

OVERVIEW OF CONCEPTS AND FINDINGS

Privacy

Privacy is conceptualized in terms of the potential for interpersonal contact through visual, auditory, olfactory, and/or tactile means. From the perspective of any given individual, privacy has two components (Archea, 1977). One is exposure, or the extent to which that person is available to (or subject to scrutiny by) another person. The other component is accessibility, or the extent to which other people are available to (or subject to scrutiny by) that person. Here social contact subsumes both exposure and accessibility.

Functions of restricted exposure and access Many different kinds of animals are known to regulate the degree of contact that they have with one another as well as with representatives of other species (Evans & Howard, 1973). Human attempts to regulate contact have been observed in all studied cultures, although the extent and the expression of these needs varies from culture to culture (Altman, 1975; Baldassare, 1978; Baldassare & Feller, 1975; Hall, 1959, 1966). Both decreasing and increasing social contact serve important functions, but discussions of privacy typically focus on the benefits of decreasing or limiting social contact. Among the purposes served by restricted contact are individual action, arousal control, self-management, and the opportunity for limited and protected communication (Altman, 1975; Bossley, 1976; Marshall, 1974).

First, although the concerted action of groups of people is often a prerequisite for achievement, there are occasions under which individual action is likely to be speedier and produce work of higher quality than is group action. In some cases, contact with other people undermines performance by diverting attention and energy from the task at hand. For example, a problem which can be approached from many different angles and which requires a complicated series of steps for solution is best solved in isolation. When interacting people work on such tasks they tend to distract and confuse one another. Thus, low levels of interpersonal contact may promote prompt, effective individual action.

Second, arousal refers to the level of physiological activation or excitation of the organism. Arousal level depends upon many factors, including the social environment. The mere presence of other people boosts the individual's overall level of arousal (e.g. Zajonc, 1965). Consequently, crowded conditions have been associated with psychophysiological and behavioral indicators of high arousal (Baum & Greenberg, 1975; Epstein, Woolfolk & Lehrer, 1981; Evans, 1979; Greenberg & Firestone, 1977; Kanaga & Flynn, 1981; Karlin & Epstein, 1979; Klopfer & Rubenstein, 1977; McCarthy & Saegert, 1978; Sieber, 1980; Webb, 1978). Removing oneself from other people's presence tends to reduce arousal and thereby promote "rest and recuperation".

Third, reduced social contact is in the interests of self-management. That is, controlling interpersonal contact helps people manage the images that they project, and hence the relationships that they have with one another. Reducing one's accessibility to other people decreases the chances that socially devalued behaviors (for example, weeping, or anger towards that other person) will be detected and create interpersonal difficulties. People, then, sometimes retreat from one another in part to "get off stage," thereby reducing the need for self-monitoring and censorship and alleviating worries about other people's perceptions and reactions (Archea, 1977; Bossley, 1976; Edney, 1976; Foddy & Finighan, 1980; Oberg & Oberg, in press).

Finally, reduced social contact can provide the opportunity for limited and protected communication, that is, for the members of a subgroup to interact without the need to take the potential reactions of the entire group into account. Simple examples include superior-subordinate interactions where the superior provides the subordinate with critical feedback, or the subordinate presents potentially threatening information to the superior. The significance of this function is that allowance must be made not only for single individuals but also for small groups of people to regulate social distance.

Functions of expanded exposure and access Usually, when people talk about privacy, they are talking about the restriction of interpersonal contact and discussions of the functions of privacy tend to focus on the benefits of reduced exposure and

access. A notable exception is Altman's (1975) conception which acknowledges that even as we sometimes seek to decrease contact with others we other times seek to increase contact. Increased exposure and access can also serve important psychological and social functions, functions that are typically discussed in the affiliation literature rather than in the privacy literature. A high degree of interpersonal contact is in the interests of group action, arousal control, uncertainty reduction, and fear control.

First, under certain conditions, group action is superior to individual action. When this is true, high levels of exposure and access are of benefit. For example, a high degree of interpersonal contact is useful when individual abilities and talents need to be pooled, when an overall sequences of tasks can be divided up into subtasks which can then be assigned to individuals, and when it is important to reach a decision which is accepted by all of the members of the group.

Second, whereas early motivational theories suggested that organisms are driven to eliminate tensions and achieve a state of quiescence, later theories acknowledged that under many conditions organisms seek heightened levels of stimulation (Berlyne, 1966). Other people can provide a welcome source of stimulation or diversion (as well as an unwelcome source of distraction). Thus, people sometimes seek to increase social contact in order to boost arousal and dispel boredom.

Third, a common theme in the social psychological literature is that people tend to feel uncomfortable when confronted with ambiguous conditions or when they feel that there are significant gaps in their knowledge. Other people provide factual or semi-factual information which helps fill in these gaps. Also, according to Festinger's social comparison theory, other people serve as sounding boards or yardsticks against which people can evaluate their opinions and feelings (Festinger, 1954). Thus, people sometimes seek increased social contact in order to reduce uncertainty and to validate their impressions.

Finally, considerable evidence suggests that contact with other people helps reduce fear. At least three mechanisms contribute to this effect (Epley, 1974). First, in many cases, there is "safety in numbers," so that contact with others decreases individual risk. Second, contact with others often triggers socially learned or classically conditioned relaxation responses which interfere with fear responses. Third, frightening conditions are often associated with an unpleasant state of emotional uncertainty, which can be reduced by means of the social comparison processes identified in the preceding paragraph.

In sum, both decreasing and increasing the amount of contact that two or more people have with each other serves important psychological and social functions. Whether or not increases or decreases are functional depends upon the person, the situation, and the activity. This has an important implication for environmental design. The goal is not to "maximize privacy," that is, to restrict people's accessibility to one another as much as possible, for there are times when high levels of contact are best. Instead, the goal is to engineer the environment in such a way as to support a whole array of options, ranging from very low to very high levels of social interaction. Then, the environment's users can select from this array those levels that are the best for a given work, recreational, or self-maintenance task.

Spatial Concepts

Closely allied to the concept of privacy are the spatial concepts of territory and personal space. A territory simply refers to a spatial area which is accessible to socially specified users (Altman, 1975; Davis & Altman, 1976; Edney, 1978; Esser, 1976; Lavin, 1981). Territories are roughly akin to "turfs" and range in size from large geopolitical areas which are the province of large numbers of people (for example, a nation or a country) to small areas such as bedrooms and berths which are assigned to specific individuals.

An important distinguishing feature of territories is that they are located as places and hence have clear geographical referents. Although walls, floors and ceilings typically define a territory's physical boundaries, the same purpose can be fulfilled by color schemes, lighting, and the strategic positioning of personal possessions. Territories are also bounded by time intervals ranging from major historical epochs (in the case of nations) down to periods of hours (in the case of motel rooms) or even minutes (in the case of lavatory stalls). Temporal demarcation is important because it means that, over time, the same limited physical area can serve multiple constituencies and multiple purposes, providing that it is possible to resolve scheduling conflicts and minimize the problems of contamination (that is, reminders of previous users).

Personal space has personal rather than geographic referents. Personal space has been described as an invisible zone, comparable to a shell or "bubble" which the individual carries around from place to place. Another person's penetration of the individual's personal space is aversive. However, such intrusions are discouraged by social customs and by defensive behaviors on the individual's part. Many studies have explored the shape and volume of personal space (for details see Altman, 1975; Evans & Howard, 1973; Hayduk, 1978, 1981, 1983; Pedersen & Shears, 1973; Sommer, 1969).

Although personal space is three dimensional and surrounds the individual, it does not precisely center on the individual, nor is it necessarily circular. The distance that an individual's personal space extends outwards depends, in part, on an approaching person's angle relative to the individual's front-and-center. For example, personal space in a given situation might extend six feet to the individual's front, but only two feet to each side and one foot to the rear. The distance that personal space extends outward from the individual also varies as a function of horizontal plane. For example, two people sitting across from each other at a library table may consider their personal spaces inviolate even though their feet are only inches apart.

Personal space requirements vary as a function of the individual. Cultural variables bear a weak relationship to privacy needs and personal space. Commonly noted is a difference between Scandinavian and other northern European cultures and Mediterranean cultures with greater personal space being required by members of the former (Altman, 1975; Baldassare, 1978; Baldassare & Feller, 1975; Sommer, 1969). Studies of sex or gender-related differences have led to highly conflicting findings, but there do appear to be two underlying themes (Altman, 1975). First, males have greater personal space requirements than do females, and people tend to maintain greater distances from males than from females. Second, people tend to require less personal space when in the presence of a person of the opposite sex than when in the presence of someone of the same sex. Studies of age-related differences show that adults generally require greater personal space than do children, and that children can be nonentities in the sense that adults ignore them at distances where an approaching fellow adult would capture attention (Altman, 1975). However, there is not appreciable variability within the age ranges most likely to fill the ranks of Space Station crewmembers. In general, poor psychological adjustment is associated with a distortion of personal space. That is, compared to well-adjusted people, poorly-adjusted people tend to have greater (or, in some cases, lesser) personal space requirements (Altman, 1975; Cavillin & Houston, 1980). Finally, people who expect conditions to be cramped or crowded seem to need less personal space than do people who have unrealistic expectations (Baum & Greenberg, 1975).

Personal space also varies as a function of the situation or environment. Holding volume constant, environmental factors which promote an impression of spaciousness reduce needs for interpersonal distance. These include relatively high illumination and the use of light colors (Baum & Davis, 1976; Mandel, Baron & Fisher, 1980; Schiffenbauer, Brown, Perry, Shulack & Zanola, 1977). Environments that are stressful or which are likely to have unpredictable elements tend to increase needs for personal space (Hayduk, 1978; McCarthy & Saegert, 1978). Within a given area, people who are located in corners tend to have greater personal space requirements than do people who do not "have their backs to the wall" (Hayduk, 1978).

Important for present purposes is evidence suggesting that environments that allow increased personal space along one dimension may reduce the need for space along another dimension. Specifically, it has been found that increased personal space along the up-down dimension decreases the need for personal space along left-right and front-back dimensions (Cochran & Urbanczyk, 1982; Savinar, 1975). In other words, people need less distance from one another in high- as compared to low-ceilinged rooms.

Finally, social variables also affect people's needs for personal space. An individual's personal space requirements tend to increase along with the other person's perceived height (Hartnett, Bailey, & Hartley, 1974). Groups that are composed in such a way that the different members' personal interests and needs complement or mesh with one another can get along with less space than can groups whose members' motives and interests clash or conflict (Altman, 1973; Altman & Haythorn, 1965, 1967a, 1967b; Haythorn, 1968, 1970, 1973; Haythorn & Altman, 1967; Haythorn, Altman & Myers, 1966). Under conditions of isolation and confinement, people with congruent or complementary needs direct their hostilities or antagonisms towards "outsiders," whereas people with competitive needs express their hostilities towards one another (Smith & Haythorn, 1972), and it may be this intragroup hostility that increases needs for personal space. This is suggested by findings that the members of groups that are characterized by positive, friendly, harmonious relations are willing to be more accessible to one another than are members of groups that are characterized by tensions or conflicts (e.g. Hayduk, 1978).

Interpersonal Distancing

Interpersonal distancing refers to the mechanisms that people use to increase or decrease interpersonal contact (Altman, 1975; Baldassare, 1978; Baum & Greenberg, 1975; Greenberg & Firestone, 1977; Vinsel, Brown, Altman & Foss, 1980). Perhaps the most pertinent interpersonal distancing mechanisms for purposes of Space Station design are person-environment mechanisms that involve the use of space and architecture. The simplest and most obvious of these is to increase or decrease physical distance from other people within a spatial area. Varying sheer physical distance from other people is a fully useful distancing mechanism only when there is ample physical space. In the Space Station and other highly contained areas, the opportunity to reduce interpersonal contact by this means is severely limited.

Another alternative is to move to an area where doors, walls, and other architectural barriers are interpositioned between the self and other people. Architectural demarcation of a relatively private area is not necessarily absolute; it is a matter of degree. A private room involving four walls, a ceiling, floor, and door is only one possibility. Any kind of full or partial architectural barrier can serve to reduce social contact. The arrangement of equipment modules, screens, and so forth in the "landscaped" office provides a good example of this. Other methods for area delineation include the creative use of color and light (Helmreich et al. 1980). For example, in an otherwise brightly lit room, two people in a dimly lit area may be set off from the other people who are present. In environments where there are severe volume and weight restrictions, the use of color and light for area demarcation is of high value.

Users of common areas often improvise territorial boundaries (Altman, 1975; Sommer, 1969). In study and eating areas, for example, occupants may use personal accoutrements or other artifacts to stake out a private area. Examples would be spreading books and other study materials over the surface of a library table, or placing a purse and coat on an adjacent seat at a lunch counter. Territorial behaviors include marking or staking out areas where other people's intrusions would be unwelcome. Allowing astronauts to carry personal items would help them improvise temporary territorial boundaries (Helmreich et al. 1980; Oberg & Oberg, in press).

Furnishings provide yet another way of regulating interpersonal distance (Altman, 1975; Sommer, 1969). Furnishings impart both physical distance and angles of orientation to users; both are important. For example, as the distance between two conversants increases, conversational efforts tend to decrease. Similarly, whereas face-to-face seating arrangements promote social interaction, oblique and back-to-back orientations do not. Furnishings which allow people to vary their distance and orientation towards one another provide users with a wide array of interpersonal options (Stuster, 1984).

Psychological interpersonal distancing mechanisms involve mental and behavioral techniques that do not involve the overt manipulation of space or the use of architectural barriers or props. Fight responses include negatively toned verbal and nonverbal displays which encourage avoidance behaviors on the part of potential intruders. Examples include statements to the effect that one is busy and shouldn't be disturbed, grunts of displeasure, glaring, assuming threatening postures, and so forth. Flight responses consist of retreating from the situation or showing signs of psychological withdrawal, such as by closing one's eyes and pretending to go to sleep.

Flight may be facilitated by the presence of certain types of visual and auditory stimuli in the environment. Specifically, complex stimuli which provide an alternative to social stimuli make it possible to decrease exposure and access. Windows are important in this regard (Helmreich et al. 1980; Connors et al. in press; Oberg, 1985; Oberg & Oberg, in press; Stuster, 1984). In space, windows provide an attractive view, and by opening up a vista, make the environment seem less cramped. Looking out of the window may at once reduce psychological distance from home while increasing psychological distance from one's companions. Similarly, pictures on walls and personal cassette recorders provide the opportunity to divert attention away from other people, thereby increasing distance from them (Baum & Davis, 1976; Helmreich et al. 1980; Boeing, 1983a; Stuster, 1984).

Finally, social contact is regulated by social normative mechanisms, that is, social rules which prescribe appropriate interpersonal distances. These include, for example, the rule that one should not bother a person who appears to be dozing or engrossed in a challenging task, and the rule that whereas one should stand close to a friend on a date, one should stand as far as possible from a stranger in an elevator.

Research by Altman and his associates highlights the importance of group norms regarding appropriate interpersonal distances (Altman, 1973; Altman, Taylor & Wheeler, 1971; Taylor, Wheeler & Altman, 1968; Taylor, Altman, Wheeler & Kushner, 1969). This research found that two person groups or dyads that remained in tact under conditions of isolation and confinement evolved social norms regarding personal space and territories early in the course of the isolation and confinement period. Members of the dyads that did not withstand the isolation and confinement period were initially disinterested in such norms but frantically tried to establish them as their interpersonal relations deteriorated. These findings suggest that the early but slow evolution of interpersonal distancing norms serves an adaptive function for isolated and confined groups.

In a related study, MacDonald and Oden (1973) observed a large number of couples that were crammed into a small dormitory facility while undergoing Peace Corps training. Although some signs of tension appeared, these couples maintained high intellectual and interpersonal standards throughout. A likely contributant to the success of this group was that its members promptly adopted and then obeyed ground rules against improper behaviors such as looking at other people while they were getting dressed, listening in on other couple's arguments, telling "dirty" jokes, and so forth.

Crowding

There is, for any individual in any situation, an existing level of social contact and a desired level of social contact. Crowding occurs to the extent that the existing level exceeds the desired level, and loneliness occurs to the extent that the existing level falls short of the mark (Altman, 1975). Whereas both crowding and loneliness are problematic, discussions of privacy in space and space-analagous environments tend to focus on crowding, no doubt because such environments promote very high levels of interpersonal contact.

A substantial number of studies have purported to examine the biological, psychological, and behavioral consequences of crowding. These include (1) demographic studies which relate the number of people per community, neighborhood, or residence to various social and psychological pathologies, (2) field experiments which involve assigning subjects to either high-density or low-density living facilities and then assessing the consequences, and (3) laboratory studies which involve manipulating the amount of contact that people have and once again assessing the consequences. Two types of experimental manipulations are used for varying density, or the number of people per unit space. One of these manipulations involves holding spatial areas constant while varying the number of people present. The other involves holding the number of people constant while varying the amount of space that is available to them. These are not entirely comparable manipulations, because altering the number of people present changes the group's dynamics. For example, if three people are housed in a small room, two people are likely to form a coalition against the third, a power situation which cannot occur in a two person group no matter how "cramped" the environment.

Varying proximity or the sheer physical distance among people is another manipulation that is commonly used in studies of crowding. In general, density and proximity are correlated: the more people per unit space, the closer they are to each other. However, this is not invariably the case. For example, a person could be at one end of a room while many other people were clustered at the other end (low proximity but high density) or two people could be standing next to each other in an otherwise vacant area (high proximity but low density).

The usual hypothesis is that packing relatively large numbers of people into relatively small spaces produces a variety of medical and behavioral pathologies. The results of early studies did not always support this hypothesis; in many cases, people who crammed into relatively small areas functioned quite well (Altman, 1975). However, the picture becomes clear when we consider the work of Altman (1975), Dean, Pugh & Gunderson (1978), Epstein (1981), Stokols (1972), Stokols, Rall, Pinner & Schopler 1973) and others who stress that it is a sequence or

chain of events that relates "crowded conditions" to psychological and social pathologies. Consideration of each link within the chain imposes some order on the overall pattern of results.

First, density and proximity are physical concepts. Relatively high density or proximity is often a necessary but insufficient conditions for crowding.

Second, perceptual and judgmental variables determine whether or not a given level of physical density or proximity gives rise to the psychological experience of crowding. Thus, researchers cannot simply manipulate density or proximity and assume that crowding has been manipulated; it is necessary to do a manipulation check to make sure that the manipulation is associated with perceptions of crowding.

Third, the threat or actual experience of crowding triggers interpersonal distancing mechansisms intended to increase interpersonal distance. If these attempts are successful, crowding is eliminated and there are no adverse effects. If, however, interpersonal distancing attempts fail, the experience of crowding persists. It is only under these latter conditions that adverse effects become likely. These adverse effects include psychophysiological effects, psychological effects, social effects, and performance effects.

Psychophysiological effects Crowding has been associated with biological and verbal indicators of stress. An association between perceived crowding and heightened blood pressure has been reported by D'Atri (1975), Evans (1979), and Paulus, McCain, and Cox (1978). Perceived crowding also correlates with increased heartbeat rate (Epstein et al. 1981; Evans, 1979). Crowding is such a reliable producer of stress in laboratory settings that Karlin, Rosen and Epstein (1979) recommend manipulating crowding in studies that are designed to use stress as an independent variable.

Other studies, using psychophysiological and self-report measures of stress, have found that anticipated crowding as well as actual crowding causes stress reactions (Baum & Greenberg, 1975). Both intrusion into personal space and visual surveillance induce stress responses independently and additively (Greenberg & Firestone, 1977), an important finding given that astronauts are sometimes under visual surveillance by ground personnel.

Psychological effects Perceived crowding and the failure of interpersonal distancing mechanisms are associated with negative emotions, and, in some situations at least, indicators of poor mental health. McCarthy and Saegert (1978) report that crowding leads to negative evaluation of the environment, and that instead of habituation to such environments, both the experience of crowding and negative attitudes intensify over time. Perceived crowding in prisons is associated with high rates of psychiatric commitment and death (Paulus et al. 1978). Comparisons of people

staffing large and small Antarctic camps have shown higher incidences of anxiety and depression in the smaller camps, where it is more difficult to evade one's associates (Gunderson, 1968, 1973). Other evidence suggests that crowding correlates with tension and anxiety (Epstein et al. 1981) and also illnesses and accidents (Dean, Pugh & Gunderson, 1975).

Social effects Crowding is associated with negative attitudes and with "social withdrawal" which can be interpreted as purposeful interpersonal distancing attempts. A number of studies reviewed by Bossley (1976) suggest that as the density of people within an area increases, social interaction decreases. In a dormitory setting, crowding was related to such avoidance mechanisms as shutting the door to one's room, going for a solitary walk, playing loud music, and rearranging furniture in the interests of privacy (Vinsel et al. 1980). Although social normative mechanisms helped maintain high intellectual and interpersonal standards among the crowded Peace Corps trainees observed by McDonald and Oden (1973), unnecessary interaction was kept to a minimum. Crowding also promotes social withdrawal and isolation in residential settings (McCarthy & Saegert, 1978).

The invasion of personal space clearly leads to overt physical withdrawal (Altman, 1975; McDowell, 1972; Sundstrom & Altman, 1976) and to nonverbal signs of withdrawal including indirect body orientations, turning or leaning away, reduced eye contact, and defensive postures including the use of crossed arms or legs to block other people and the redirection of conversation away from intimate topics (Greenberg & Firestone, 1977; Evans, 1979; Sundstrom & Altman, 1976). Even anticipated crowding prompts subjects to avoid eye contact and position themselves in corners or other protected locations (Baum & Greenberg, 1975).

Performance effects One way that crowding may affect performance is through stress that has well-documented effects on performance. The stress-free individual lacks motivation; the highly stressed individual is motivated but proves to be disorganized and ineffective. Consequently, there is a curvilinear or inverted-U relationship between stress and performance, with moderate stress associated with optimal performance. The inflection point, where optimal stress shades into excessive stress, depends upon several variables, most notably the difficulty of the task relative to the performer's skills and abilities. In the case of tasks that the performer finds easy, a relatively high level of stress is required before adverse performance effects are encountered. In the case of tasks that the performer finds difficult, relatively low levels of stress may have adverse effects. From this line of reasoning, it may be deduced that crowding is more likely to lead to performance decrements in the case of tasks that are poorly learned or that involve complex sequences of cognitive and motor activities than in the case of tasks that are well learned or involve simple sequences of work activities.

The effects of stress on performance are probably more complex and far reaching than suggested by this simple crowding - stress-performance model (Langer & Saegert, 1977). First of all, crowding may cause people to redirect their energy away from the task at hand to try to deal with the crowding. Second, whereas short-term crowding and stress may cause a person to apply himself or herself to the work at hand, long-term crowding and stress are likely to be reflected in wear-and-tear on the organism. Finally, even when crowding is not evidenced in errors, it may be evidenced in absenteeism, turnover, and other undesirable withdrawal behaviors.

The little available "hard" data that relates crowding to performance do suggest that crowding is typically counter-productive. In comparison to dyads in two-person dormitory rooms, triads in the same sized rooms earned lower grades, a performance drop that was eliminated when the triads were reassigned to three-person rooms later on (Karlin et al. 1979). Increasing group size, decreasing room size, and decreasing proximity all undermined performance in an experiment by Paulus, Annis, Seta, Schkade, & Mathews (1976). In addition to showing elevated blood pressure and increased heartbeat rate, crowded subjects in another study took longer to determine the appropriate strategy for performing a task, made more errors, and evidenced higher levels of frustration and hostility (Evans, 1979).

Particularly relevant is work by Saegert and her associates. In one of these studies, subjects in crowded train stations could perform fewer relevant tasks (finding out train departure times, locating restrooms, and so forth) than could subjects under less crowded conditions (Saegert, Mackintosh, & West, 1975). In another study, crowding did not affect department store shoppers memories for descriptions that they had earlier written, but it did hamper their ability to draw complete and accurate maps of the areas that they had covered (Saegert et al. 1975). In still another study, supermarket shoppers were given grocery lists and asked to find the products that would most economically satisfy the list (Langer & Saegert, 1977). Some subjects were informed about the aversive effects of high density conditions, and others were not. Compared to noncrowded shoppers, crowded shoppers found fewer of the items that appeared on their lists, and found the most economical items less often. Additionally, crowded subjects reported that they liked the environment less, felt that other people were more likely to get in the way, found it more difficult to locate the designated classes of consumer goods, and found it more difficult to make selections among items within each class. Importantly, forewarning had a positive effect. Shoppers who had been alerted to the likely psychological reactions to crowding performed better than did shoppers who were not given this insight.

Two provisional conclusions are offered. First, when people are simply working in each others' presence, crowding may facilitate the performance of simple tasks but impair the performance of complex tasks. Second, when work involves a number of people moving into and out of the same space, queing up for tools, supplies, and other resources, then these people are likely to actively interfere with one another and crowding hurts performance. This holds true in spaceflight as well as nonspaceflight environments.

PRIVACY AND PERSONAL SPACE IN OUTER SPACE

People's efforts to regulate interpersonal contact have been noted in all groups studied thusfar, and spacecrews are no exception. Several factors, including the small interior volume of spacecraft and the presence of external monitors, have focused attention on limiting, rather than increasing, astronauts accessibility to one another. Privacy appears to be a major concern of many authors who have addressed the social and psychological dimensions of spaceflight, including Berry (1973), Bluth (1980, 1981, 1982), Boeing (1983a, 1983b), Connors et al. (1985), Cooper (1976), Helmreich et al. (1980), Kanas and Fedderson (1971), Oberg (1985), Oberg and Oberg (in press), Sieber (1980), and Stuster (1984).

Privacy Needs

Both American and Soviet crews have expressed needs for more privacy aboard their spacecraft (Bluth 1980, 1981, 1982). For example, Skylab astronauts have commented on needs for places to be alone, private sleeping quarters, and locations to store personal belongings (Bluth, 1981). Observations of Salyut crews suggest that rather than adapting to crowded conditions over time cosmonauts needs to restrict social contact increase as spaceflight continues (Boeing, 1983a). An example of privacy-seeking aboard spacecraft is provided by Salyut cosmonaut Lebedev, who waited until his fellow astronauts were asleep and then slipped into the attached Soyuz to read long-awaited mail from home (Oberg & Oberg, in press). Unsatisfied privacy needs may be the underlying cause of other complaints such as about other people's poor personal hygiene (Stuster, 1984).

Each of the functions that restricting social contact serves on Earth will also have to be served in space. First, individual action may be required to perform certain technical and scientific tasks. Limited contact will be required so that the individual astronaut can concentrate on the task and perform a complicated sequence of steps.

Second, certain points within missions are likely to be accompanied by high degrees of stimulation. Social stimulation can further elevate overall arousal. The ability to restrict social contact can help astronauts keep arousal within acceptable levels.

Third, astronauts can profit from "down time" which can be used for managing the images that they project to other people. Spacefarers are subjected to multiple stresses, including isolation and confinement, heavy work schedules complicated by weightlessness, and a certain amount of deprivation and danger. Common reactions in analagous environments include depression, irritability, and social tensions (Connors et al. 1985; Harrison & Connors, 1984). Presumably an accompaniment to such stress will be increased needs to get "off stage" and regain one's composure.

Fourth, any needs for "limited and protected communication," that is, needs to communicate with a second party in the absence of third parties --- will have to take place within the close confines of the spacecraft. Accommodations should be made for private conversations aboard the spacecraft (Stuster, 1984). Spacecraft/Earth communications have the potential of posing special problems. Specifically, telecommunications links may make it possible for outsiders to infringe upon the privacy of the crew. External surveillance has, for example, been implicated in tense relations between Skylab III astronauts and ground personnel (Cooper, 1976). Additionally, several writers have noted needs for telecommunications systems that make it possible for astronauts to have private conversations with family members back home (Oberg & Oberg, in press; Stuster, 1984).

But at the same time, one can envision circumstances under which very high degrees of interpersonal contact are warranted. First, many tasks require collective action. A high degree of person-to-person contact is often essential or desirable for accomplishing these tasks.

Second, on some types of missions, at least, there may be periods of relative inactivity (Connors et al. 1985; Harrison & Connors, 1985). In the course of such missions, the ability to increase social stimulation may be in the interests of optimal arousal.

Third, absence from Earth weakens links with families and friends who normally provide information useful for making sense out of the world and for placing attitudes and emotions in perspective (Connors et al. 1985; Helmreich et al. 1980). Highly restricted contact with fellow space travellers or the absence of telecommunications links to associates on Earth would further deprive astronauts of the kinds of social inputs that are useful for social comparison processes.

Fourth and finally, contact with others often reduces fear. Under certain kinds of stressful conditions, psychological well-being and performance will be served not by limiting exposure and access but by promoting them to a high degree.

Spacecraft of the future thus need to make provision for high, intermediate, and low degrees of interpersonal contact. Designs which accommodate people's needs to be alone but which ignore situations calling for social interaction are as deficient as designs which fail to take into account people's needs for solitude.

Territories and Personal Space

Spaceflight analysts have also discussed the role of territories and personal space. At the heart of the matter is the fact that spacecraft are necessarily smallish, and much of their interior space is occupied by propulsion, life support, scientific and industrial equipment. Thus, there is not much territory to be assigned, and of the territory that can be assigned, much has to be assigned to multiple users. The Boeing report on Salyut recommends that 20 percent of the spacecraft should be designated as private (Boeing, 1983a).

Perhaps the top priority for this space is private sleeping quarters (Boeing, 1983a, 1983b; Bluth, 1981; Helmreich et al. 1980; Oberg & Oberg, in press; Stuster, 1984). There are strong recommendations against "hot bunking"---that is, having two or more people use the same bed or bunk in shifts (Boeing, 1983b; Stuster, 1984). Also, sound-proofed and odor-proofed toilet facilities, located in inconspicuous areas, are considered a must (Oberg & Oberg, in press; Stuster, 1984). Whereas it may or may not be possible to assign specific areas to specific individuals or groups, it may be useful to divide territories along work-nonwork or other functional lines (Boeing, 1983a).

Temporary territories may provide useful substitutes for permanent territories. Temporary territories can be established by means of movable partitions and screens, folding walls, the creative use of lighting, and so forth (Helmreich et al. 1980). One of the many advantages of allowing astronauts to carry personal items would be that it would allow them to stake-out temporary territories (Boeing, 1983a; Helmreich et al. 1980; Oberg & Oberg, in press; Stuster, 1984). Symbolic or token territories in the form of small storage areas for personal items may also be of use (Boeing, 1983a; Helmreich et. al. 1980; Oberg & Oberg, in press; Stuster, 1984).

As in the case of territories, personal space is limited by virtue of the typical spacecraft's modest interior dimensions. Pertinent here are intentions of staffing the Space Station with astronauts representing both sexes, a range of ages, and many different nationalities. In terms of personal space requirements, full integration of women into crews offers certain advantages.

As already noted, women seem to require less personal space than do men, and mixed-sex pairs seem to tolerate higher degrees of proximity than do pairs consisting of two men or two women. Age differences are likely to be inconsequential within the age ranges envisioned for occupants of the Space Station. However, the inclusion of people from many different cultures is likely to complicate the task of satisfying everyone's personal space requirements.

Not well understood are the effects of locomotion in three dimensions on personal space needs and reactions to invasion. There is very little research bearing on this, but research by Hartnett et al. (1974) suggests that being approached "from above" infringes upon personal space at a greater distance than does being approached on the same horizontal level.

Interpersonal Distancing

At the same time that isolation, confinement, and other spaceflight conditions enhance privacy needs, they complicate the use of everyday interpersonal distancing tactics. Person-environment mechanisms are restricted by the volume and weight limitations of spaceflight environments. As already noted, there is not a great deal of interior space, and, of the space that is available, it may be possible to allocate very little to private areas. Additionally, walls, doors, and other barriers are likely to be scarce, and soundproofing may not be the best.

The limited availability of fixed architectural barriers has two implications. One is that screens, shades, and other temporary barriers will have to be used, as described in the preceding section. The other implication is that light, colors, and other design features that cost little in terms of space and weight should be considered as potential distancing mechanisms.

Psychological interpersonal distancing mechanisms, like person-environment mechanisms, are also likely to be limited by the conditions of spaceflight. Typically, psychological mechanisms involve verbal and nonverbal communications. Both types may be degraded in space (Connors et al. in press). In some spacecraft environments, verbal communication is impaired due to such factors as high ambient noise and atmospheric conditions that are less conducive to sound transmission than is the normal Earth atmosphere. Much of the communication upon which interpersonal distancing depends involves very subtle nonverbal communication: shifts of position, changes of facial expressions, and so forth. Weightlessness impacts two forms of nonverbal communication. First, locomotion difficulties and the fact that locomotion occurs in three dimensions complicates the processes of physical distancing and the transmission of subtle proxemic cues. Second, a certain "puffiness" and slightly distorted facial expression is commonly reported under conditions of

weightlessness. Thus, there may be a degrading of the interpersonal distancing cues normally imparted by postures, gestures, and facial expressions.

Attitudinal barriers may work against the use of normal "fight and flight" responses to crowding. People in isolated and confined settings are often highly sensitive to the need to maintain cordial interpersonal relations, and may be intolerant of minor displays of anger or hostility because they are afraid that such displays may escalate to dangerous levels. Similarly, the high degree of interdependence of space crew members, coupled with the perception that withdrawal may somehow signify a loss of emotional stability, may discourage flight responses.

Psychological mechanisms should remain viable options if astronauts recognize that people need to limit their accessibility to one another, and that aggressive and withdrawal tactics are among the means for setting such limits. Indeed, it can be argued that mild fight or flight reactions that produce the desired effect of increasing interpersonal distance diminish the chances of severe reactions that can pose a significant threat to the group.

Finally, social normative mechanisms for regulating interpersonal distance evolve over time as a result of social interaction. The spaceflight environment is a relatively new and changing environment, and a full range of customs and conventions is yet to evolve. There is, however, some evidence of evolving norms: for example, the convention against floating over a table that is in use by diners (Cooper, 1976). Group development strategies which sensitize crewmembers to the importance of privacy and encourage an airing of privacy concerns could help a crew itself develop an appropriate set of norms.

TOWARDS A MODEL OF SITUATIONAL PRIVACY

This section presents a quantitative model of privacy, interpersonal distancing, and performance. This situational privacy model draws heavily on work by Altman (1975) and by Argyle and Deane (1965).

Overview

The situational privacy model of performance is an environment-task matching model. It states that the type and level of social contact promoted by the environment (environmental potential) should approximate as much as possible the type and level of social contact required by the task (task requirements). There are four types of contact that correspond to four sensory modalities or communication channels: visual, auditory, olfactory, and tactile. Although the model attempts to

be complete and takes each modality into account, it is through sight and hearing that the most voluminous and efficient human communication takes place. The visual and auditory dimensions are the most critical and have the most complex design implications.

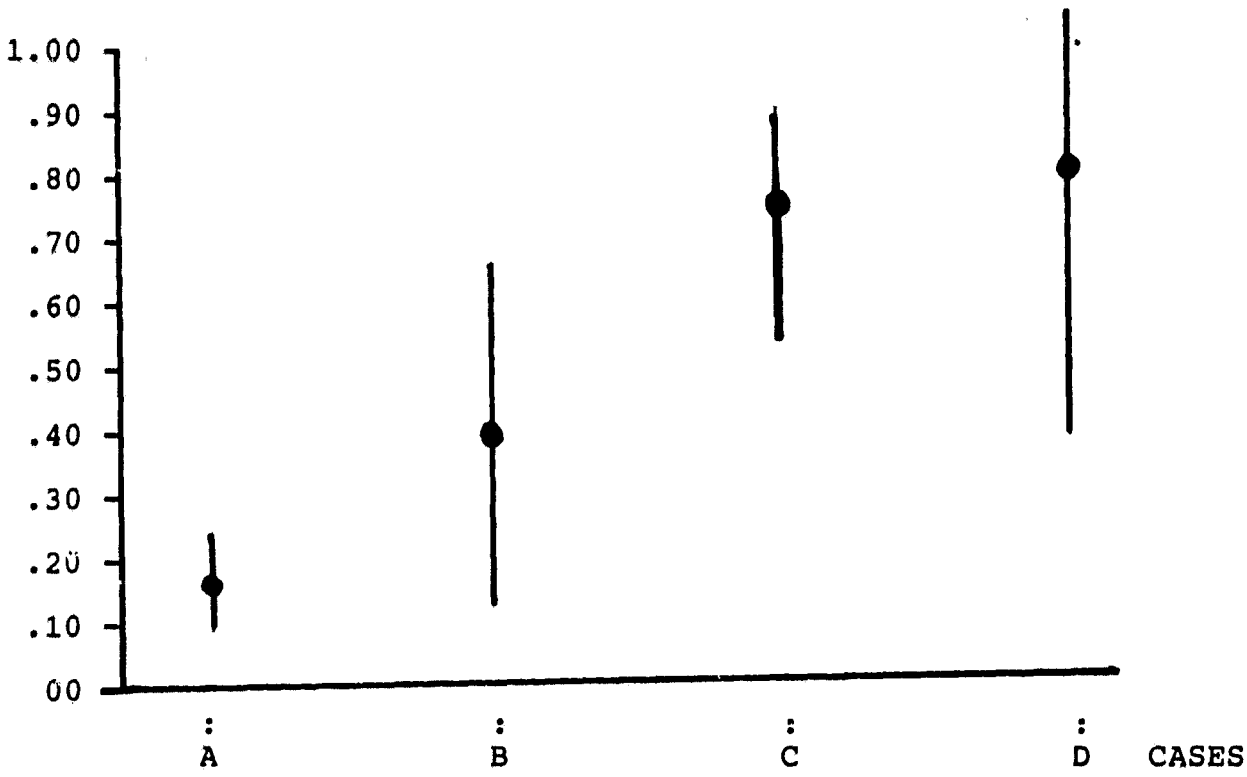
Both the environment's social potential and the task's social requirements can be expressed in terms of momentary values, measures of central tendency or statistical averages, and measures of statistical variability, or range. If the level of social contact provided by the environment appreciably exceeds or falls short of the level of social contact required by the task, performance may suffer.

Basic Concepts

A situation consists of two components: an environment and a task. An environment is a physical and social setting in which work, recreation, or other human activity takes place. Environments provide their users some degree of interpersonal or social contact. Environmental potential refers to the degree or degrees of interpersonal contact that an environment affords its users.

The momentary environmental potential is the degree of interpersonal contact that the environment affords its users at a particular point in time. The environmental set point is the average or mean amount of interpersonal contact that occurs in the environment over an extended period of time. The environmental range is bracketed by the maximum and minimum amounts of interpersonal contact that occur in the environment. Set points are estimates of central tendencies and ranges are estimates of variability.

Environmental set points may support high or low degrees of social interaction and environmental ranges may be narrow or wide (Figure 1). For example, an individual work cubicle that is separated from other work cubicles by walls or curtains would have a low environmental set point (because, when occupied, it is occupied by only one worker) and essentially no range (because it supports only one worker). A spacious commander's room would illustrate an environment with a low set point (most of the time it houses only the commander) but a wide range (because groups of subordinates can be assembled for meetings). A cockpit which requires a crew of four would represent a moderate environmental set point and a narrow environmental range. Finally, a ward room or other setting which accommodates a varying number of users and offers seating or other options that accommodate an array of different interpersonal contact needs would have relatively high environmental set points and ranges. The key characteristic of environments with high ranges is that they are user definable and redefinable, and can hence satisfy a range of interpersonal contact needs.



CASE	SET POINT	RANGE	EXAMPLE
A	low	narrow	work cubicle
B	low	wide	commander's room
C	high	narrow	cockpit
D	high	wide	ward room

FIGURE 1

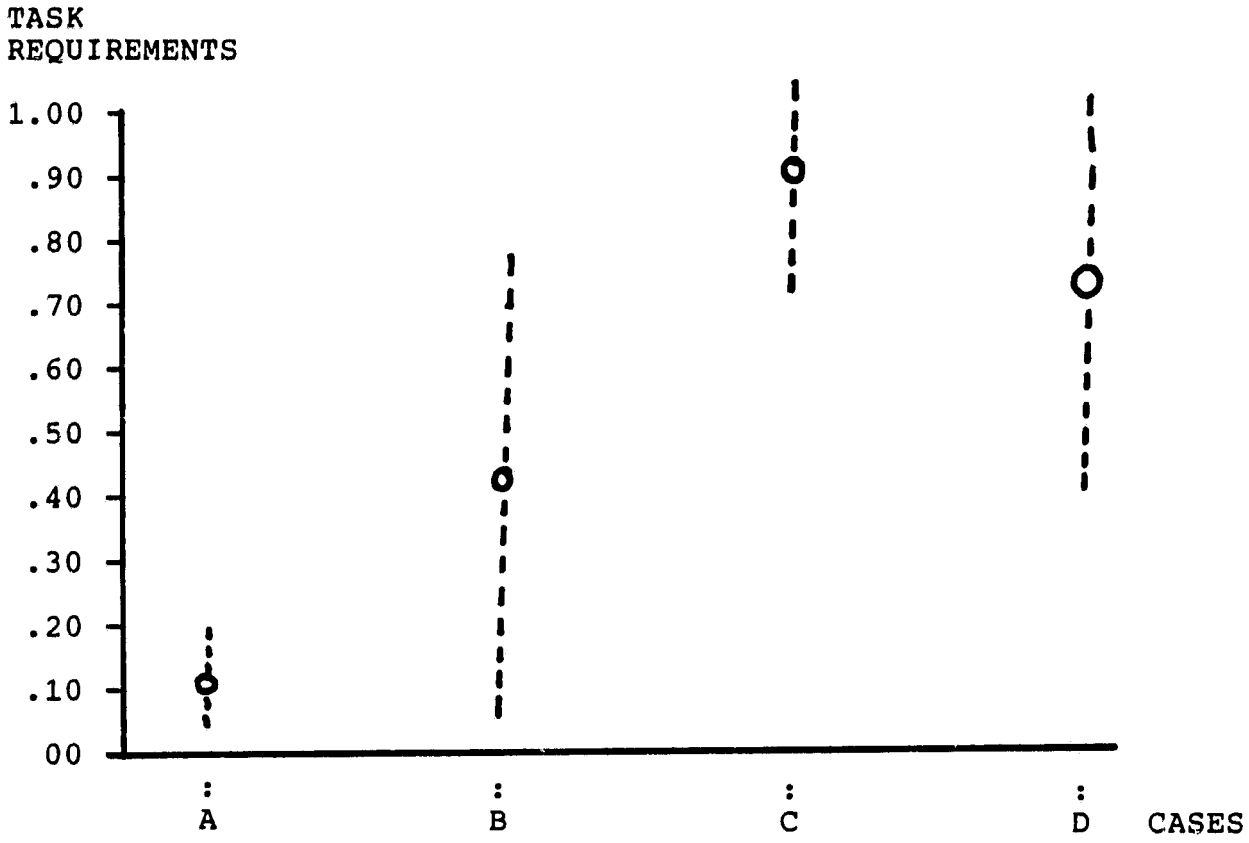
ENVIRONMENTAL SET POINTS AND RANGES
(Hypothetical Cases)

A task in this model is any goal-directed activity in any sphere of endeavor including work, self-maintenance, and recreation. Whether or not a goal is reachable and the relative efficiency with which it is attained depends in part on the degree of interpersonal contact that a given performer has with other people. As noted in the literature review, relatively low degrees of interpersonal contact foster goal attainment when the task is structured for individual action, when it involves reductions in excitation or arousal, when it requires people to "get off stage," and when it is necessary or desirable to confer with a limited number of other people in the absence of third parties. A high degree of interpersonal contact is beneficial when the task is structured for group action, when it involves boosts in arousal, when it requires gathering information from other people, and when it involves coping with certain kinds of threat. Thus, different tasks, like different environments, are associated with different degrees of social interaction.

Task requirement refers to the degree of interpersonal contact or social interaction that is necessary or desirable for performing a task. The momentary task requirement is the degree of interpersonal contact that a task requires at a particular point in time. The task set point refers to the average amount of interpersonal contact required over the course of performing a task. A task range brackets the greatest and least amounts of interpersonal contact required by the task.

Task requirements may involve high or low setpoints and narrow or wide ranges (Figure 2). For example, computer programming or any other tasks which require a high degree of concentration and which only occasionally benefit from other people's inputs would involve a low task set point and a narrow task range. Piloting, which may involve extended periods of solitary activity punctuated by brief periods of intensive teamwork would represent a moderately low task set point and a moderately high task range. Briefings, which involve assembling an entire crew, would involve high task set points and narrow task ranges. Finally, scientific activities which generally require teamwork but which may also require periods of intense individual concentration involve high task set points and ranges. Although these examples involve work tasks, varying task set points and ranges are also associated with different self-maintenance and recreational activities.

Situational privacy refers to the match or goodness of fit between the environmental potential and the task. Situational privacy exists to the extent that there is a match between environmental momentary potentials, set points, and ranges, on the one hand, and task momentary potentials, set points, and ranges, on the other. Situational discrepancy refers to the degree of misalignment of environment and task. According to the model, situational privacy is directly related to performance and situational discrepancy is inversely related to performance.



CASE	SET POINT	RANGE	EXAMPLE
A	low	narrow	computer programming
B	low	wide	piloting
C	high	narrow	crew briefing
D	high	wide	scientific activity

FIGURE 2

TASK REQUIREMENT SET POINTS AND RANGES
(Hypothetical Cases)

Operationalizing Environmental Potential

As already noted, interpersonal contact occurs through one or more sensory channels or modalities including the visual, auditory, olfactory, and tactile. Environmental potential refers to the degree or degrees of visual, auditory, olfactory, and tactile contact that an environment affords its users. Environmental potential is expressed in terms of quantitative estimates of the amount that is present at any given point in time (momentary environmental potentials), quantitative estimates of central tendencies (environmental set points), and quantitative estimates of variability (environmental ranges).

Application of the model begins with a list of all of the environment's users. Any number of users may be entered in, but for purposes of illustration we assume six users (designated a,b,c,d,e,f) since this is a likely size for an initial Space Station crew. These potential users are then considered, two at a time, in all possible combinations, so that with six potential users it is necessary to consider 15 possible pairs (ab, ac, ad, ae, af, bc, bd, be, bf, cd, ce, cf, de, df, ef). Considering, in turn, each of the four types of contact, three questions are addressed. In this environment, at this point in time, what amount of contact do these two people have along this dimension? In this environment, what is the maximum amount of contact these two people can have along this particular contact dimension? What is the minimum or least contact these two people can have along this particular dimension? In effect, the maximum environmental potential reflects the greatest amount of closeness or contact that is possible when the two members of the pair are actively seeking each other out, and the minimum reflects the greatest distance that the two people can maintain when they are actively striving to avoid one another.

Computations are based on summing scores across all pairs. The maximum and the minimum establish environmental potential range; the average establishes the environmental set point. By asking each question separately for each type of contact, it is possible to distinguish among visual, auditory, olfactory, and tactile ranges and set points. Summing across the modalities and dividing by the number of modalities provides composites or overall estimates of ranges and setpoints. Again it should be stressed that for all intents and purposes, visual and auditory contact deserve the closest consideration.

Immediacy or I is the quantitative estimate of the degree of contact between the members of any given pair of people along any given contact dimension. Immediacy refers to the intensity, quality, or strength of contact. Immediacy scores range from 0 to 1, with high scores indicating greater immediacy, or a higher degree of contact. One way of viewing immediacy is in terms of a signal-to-noise ratio, with the other member of the pair providing the individual with a "signal" and all other inputs through the same modality providing the "noise."

Immediacy depends, first of all, on the members of the pair being sufficiently close to one another to decode one another's signals. Immediacy also depends on the presence or absence of blocks, filters, illusory barriers, and distractors which interfere with interpersonal contact.

Blocks refer to features which effectively eliminate all contact of a particular type. For example, doors, walls and other architectural barriers can completely eliminate visual and tactile contact, and, in many cases, auditory and olfactory contact as well.

Filters refer to environmental features which degrade but do not eliminate contact of a given type. For example, poor illumination may obscure facial features (thereby filtering out the information contained in facial features) while leaving posture, at least in silhouette form, in full view.

Illusory barriers perceptually, rather than physically, separate people from one another. Illusory barriers include personal possessions used as visual "markers" to delineate personal space or to define a territory. An example of the former would be personal effects spread on a table intended to accommodate more than one user; an example of the latter would be the use of photos, posters, and other personal memorabilia to personalize an area near a dormitory bunk. Illusory barriers serve as signals to others to maintain distance.

Distractors are stimuli which potentially interfere with social interaction. They include windows, interesting works of art, television shows, reading materials, and the like, that provide alternatives to social contact. Distractors reduce immediacy by allowing one person to mentally tune another person out.

There are two promising techniques for operationalizing immediacy. These are the statisticized group technique and the mathematical theory of communication.

Based upon the pooling of expert judgments, the statisticized group technique could be applied in the near future. There is certainly ample precedent in psychology and in design for using expert judgments for obtaining quantitative estimates. There is also ample precedent for using groups to make decisions: applications of brainstorming, nominal group, and delphi procedures are examples of this. Compared to these better known procedures, the statisticized group technique is very simple. All it involves is having a number of people make independent quantitative estimates which are then statistically pooled or averaged. When these people are "expert" in the sense that they are likely to be fundamentally correct if inaccurate, the average judgment tends to be of substantially higher accuracy than any individual judgment (Lorge, Fox, Davis & Brenner, 1958). Through combining individual judgments into a group score,

different judges' mistakes cancel each other out, and there is a reduction in error. The statisticized group technique is a useful technique provided that the judges are expert in the sense that they are able to make estimates that fall in the right "ballpark," and that each judge's estimate is independent in that it is not influenced by other people's judgments.

For heuristic purposes, it is thus proposed to have a group of expert judges (environmental psychologists, mission personnel, and so forth) independently estimate, on 0 to 100 scales, the momentary, maximum, minimum, and average amounts of visual, auditory, olfactory and tactile contact that the members of any given pair of individuals are likely to have in a given Space Station area. Such judges would require access to very detailed descriptions and renderings of the Space Station, or, better yet, to full size mock-ups, perhaps containing mannikins of astronauts performing a variety of work, recreational, and self-maintenance activities. For computational purposes, their judgments are then averaged and transformed to fit a 0 to 1 scale.

Promising in the long run is the mathematical theory of communication as initiated by Shannon and Weaver (1949). This provides a formalized account of the information flow from transmitter to receiver along any given channel. It provides quantitative estimates of such variables as channel capacity, rate of information flow, redundancy, and noise. Although largely developed to account for the flow of information between electronic devices, it is also applicable to human communication. This formal approach is reflected in open systems theory treatments of interpersonal and organizational communication (Katz & Kahn, 1978; Miller, 1978). It might be possible to define immediacy in terms of the availability and capacity of different interpersonal communication channels (visual, auditory, olfactory, and tactile), the rate of information flow along these channels, and noise. Although this approach might circumvent some of the shortcomings associated with relying on human estimates, it would require extensive long-term development.

Environmental potentials are computed as follows:

```
EPmax  = (VPmax + APmax + OPmax + FPmax)/4
EPmin  = (VPmin + APmin + OPmin + FPmin)/4
EPm    = (VPm + APm + OPm + FPm)/4
EPs    = (EPm1 + EPm2 + EPm3 + ...EPmn)/n
EPr    = EPmax - EPmin

VPmax = (maxVIab + maxVIac + maxVIad +  ...maxVIef)/n
VPmin = (minVIab + minVIac + minVIad +  ...minVIef)/n
VPm   = (mVIab + mVIac + mVIad + ...mVIef)/n
VPs   = (VPm1 + VPm2 + VPm3 + ...VPmn)/n
VPr   = VPmax - VPmin
```

APmax = (maxAIab + maxAIac + maxAIad + ... maxAIef)/n
APmin = (minAIab + minAIac + minAIad + ... minAIef)/n
APm = (mAIab + mAIac + mAIad + ...mAIef)/n
APs = (APm1 + APm2 + APm3 + ...APmn)/n
APr = APmax - APmin

OPmax = (maxOIab + maxOIac + maxOIad + ...maxOIef)/n
OPmin = (minOIab + minOIac + minOIad + ...minOIef)/n
OPm = (mOIab + mOIac + mOIad + ...mOIef)/n
OPs = (OPm1 + OPm2 + OPm3 + ...OPmn)/n
OPr = OPmax - OPmin

FPmax = (maxFIab + maxFIac + maxFIad + ...maxFIef)/n
FPmin = (minFIab + minFIac + minFIad + minFIef)/n
FPm = (mFIab + mFIac + mFIad + ...mFIef)/n
FPs = (FPm1 + FPm2 + FPm3 + ...FPmn)/n
FPr = FPmax - FPmin

Where:

EP = environmental potential
VP = visual potential
AP = auditory potential
OP = olfactory potential
FP = tactile (feel) potential

VI = visual immediacy
AI = auditory immediacy
OI = olfactory immediacy
FI = tactile immediacy

I = immediacy between any two individuals (a,b) on the specified contact dimension

= (Ji1 + Ji2 + Ji3 + ...Jin)/100 in

where

Ji1 ... Jin = independent judgments of immediacy on a 0 - 100 scale

in = number of independent judgments

ab, ac, ad, ... ef = crewmembers a through f considered two at a time
max = maximum
min = minimum
m = momentary

n = number of cases
Pm1, Pm2, etc., = repeated estimates of momentary potential
s = setpoint
r = range

Operationalizing Task Requirements

Task requirements refer to the degree of visual, auditory, olfactory, and tactile contact that is useful for getting a job done, whether that job involves work, recreational, or self-maintenance activities. Task requirements, like environmental potentials, are expressed in terms of momentary values, set points, and ranges.

As in the case of computing environmental potential, computations are based on summing across all possible pairs of crewmembers. The maximum and the minimum establish the task range, and the average, the task set point. Again by considering separately visual, auditory, olfactory, and tactile contact, it is possible to distinguish among the four different types of requirements and also to derive overall estimates.

The quantification of task requirements parallels the quantification of environmental potential. Specifically, again all possible pairs of crew members (ab, ac, ad, ... ef when n=6) are considered. In this case the questions are "What is the amount of (visual, auditory, olfactory, tactile) contact required by this task at this time?" "What is the minimum amount of contact required by this task? What is the maximum amount of contact required by this task?

Social interdependence or S is the quantitative estimate of the degree of contact that the task requires between any two people along any given contact dimension. Whereas immediacy scores reflect achieved or achievable levels of contact, social interdependence scores reflect desirable levels of social contact. Like immediacy scores, social interdependence scores are based upon the statistical pooling of expert judgments and ultimatelt assume values between 0 and 1.

Task requirements are computed as follows:

```
TRmax  = (VRmax + ARmax + ORmax + FRmax)/4
TRmin  = (VRmin + ARmin + ORmin + FRmin)/4
TRm    = (VRm + ARm + ORm + FRm)/4
TRs    = (TRm1 + TRm2 + TRm3 + ...TRmn)/n
TRr    = TRmax - TRmin

VRmax = (maxVSab + maxVSac + maxVSad +  ...maxVSef)/n
VRmin = (minVSab + minVSac + minVSad +  ...minVSef)/n
VRm   = (mVSab + mVSac + mVSad + ...mVSef)/n
VRs   = (VRm1 + VRm2 + VRm3 + ...VRmn)/n
VRr   = VRmax - VRmin
```

```
ARmax = (maxASab + maxASac + maxASad + ... maxASef)/n
ARmin = (minASab + minASac + minASad + ... minASef)/n
ARm   = (mASab + mASac + mASad + ...mASef)/n
ARs   = (ARm1 + ARm2 + ARm3 + ...ARmn)/n
ARr   = ARmax - ARmin

ORmax = (maxOSab + maxOSac + maxOSad + ...maxOSef)/n
ORmin = (minOSab + minOSac + minOSad + ...minOSef)/n
ORm   = (mOSab + mOSac + mOSad + ...mOSef)/n
ORs   = (ORm1 + ORm2 + ORm3 + ...ORmn)/n
ORr   = ORmax - ORmin

FRmax = (maxFSab + maxFSac + maxFSad + ...maxFSef)/n
FRmin = (minFSab + minFSac + minFSad + minFSef)/n
FRm   = (mFSab + mFSac + mFSad + ...mFSef)/n
FRs   = (FRm1 + FRm2 + FRm3 + ...FRmn)/n
FRr   = FRmax - FRmin
```

Where:

TR = task requirement
VR = visual requirement
AR = auditory requirement
OR = olfactory requirement
FR = tactile (feel) requirement

VS = visual social interdependence
AS = auditory social interdependence
OS = olfactory social interdependence
FS = tactile social interdependence

S = social interdependence between any two individuals (a,b) on the specified contact dimension

= (Js1 + Js2 + Js3 + ...Jsn)/100 in

where

Js1 ... Jsn = independent judgments of social interdependence on a 0 to 100 scale

in = number of independent judgments

ab, ac, ad, ... ef = crewmembers a through f considered two at a time
max = maximum
min = minimum
m = momentary
n = number of cases
Rm1, Rm2, etc., = repeated estimates of momentary requirements
s = setpoint
r = range

Estimating Situational Discrepancy

Situational privacy exists to the extent that environmental potentials and task requirements are aligned. Situational discrepancy exists to the extent that environmental potentials and task requirements are mismatched or misaligned.

Situational discrepancy is the absolute value of the difference between an estimate of environmental potential and a corresponding estimate of task requirements. Computations may be based on momentary potentials, set points, or ranges. Thus:

$$EPm - TRm = Dm$$

$$EPs - TRs = Ds$$

$$/EPmax - TRmax/ + /EPmin - TRmin/ = Dr$$

where:

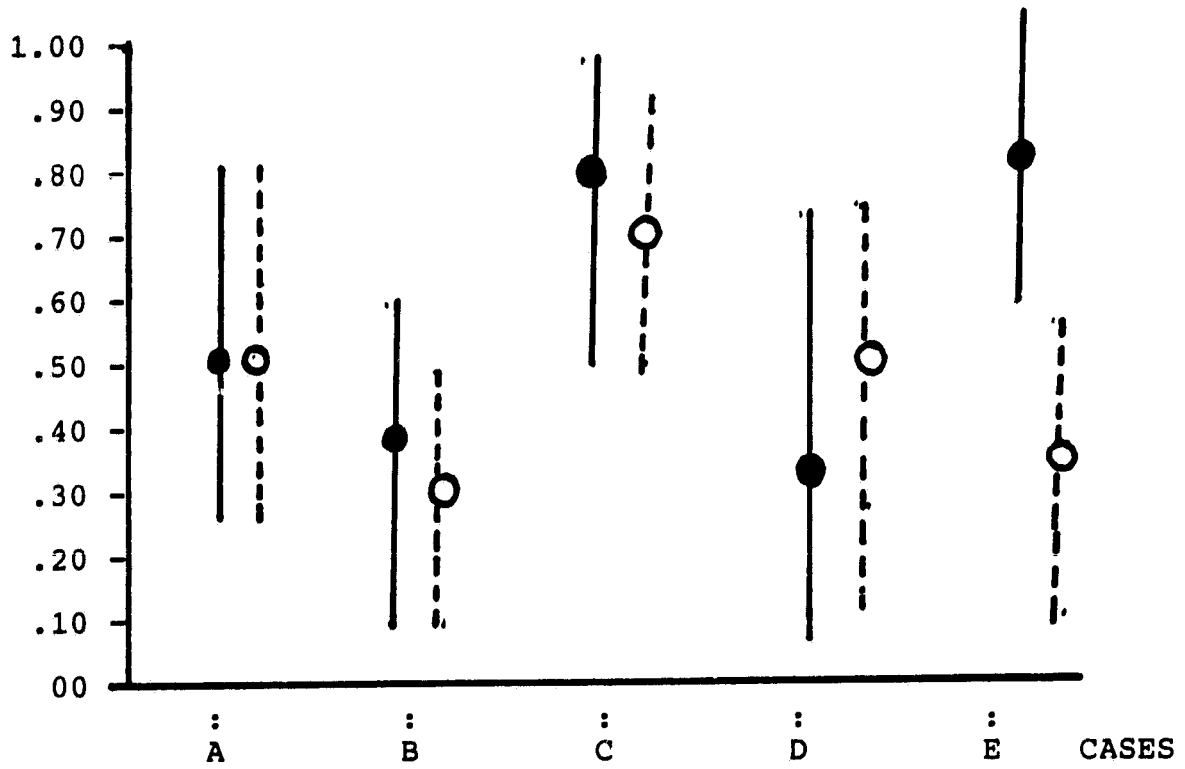
EPm	=	momentary environmental potential
TRm	=	momentary task requirement
EPs	=	environmental potential set point
TRs	=	task requirement set point
EPmax	=	maximum environmental potential
EPmin	=	minimum environmental potential
TRmax	=	maximum task requirement
TRmin	=	minimum task requirement
Dm	=	momentary situational discrepancy
Ds	=	setpoint (average) situational discrepancy
Dr	=	range discrepancy

Examples of matches and mismatches of environmental potentials and task requirements are presented in Figure 3.

Situational Discrepancy and Performance

The absolute value of the situational discrepancy, /D/, is negatively correlated with performance. When /D/ is appreciable, then either attention is diverted away from the task to engage in interpersonal distancing activities until the appropriate level of interpersonal contact is attained, or the task cannot be satisfactorily performed. As shown in Figure 4, situational discrepancies can fall into one of three ranges. These three ranges have different implications for well-being and performance.

The first is the range of acceptability. This is a "range of no difference" that surrounds the environmental set point. Discrepancies that fall within this range are not noxious, do not prompt interpersonal distancing behaviors, and do not have measurable effects on performance.



CASE	DESCRIPTION	EFFECT
A	situational privacy	peak performance
B	slight setpoint discrepancy	negligible decrement
C	moderate setpoint discrepancy	temporary inefficiency
D	severe setpoint discrepancy	severe impairment
E	nonoverlapping ranges	total impairment

FIGURE 3

SITUATIONAL DISCREPANCIES AND PERFORMANCE CONSEQUENCES
(Hypothetical Cases)



A: Obtained Environmental Setpoint and Range
B: Range of Acceptability for Task Requirements
C: Ranges of Adjustability for Task Requirements
D: Ranges of Unacceptability for Task Requirements

FIGURE 4

SITUATIONAL DISCREPANCY RANGES
(Hypothetical Cases)

Second there is the range of adjustability. Task requirements that fall outside of the range of acceptability but within the environmental range fall within the range of adjustability. Situational discrepancies of this magnitude are likely to have a temporary adverse effect on performance. Some time may be lost on interpersonal distancing, but since the appropriate level of interpersonal contact is ultimately achieved, the job does get done.

Finally there is the range of unacceptability. Task requirements that fall outside of the environmental potential range, that is, that require either a higher or lower level of social contact than can be achieved within the environment, fall within the range of unacceptability. When this occurs, performers must either abandon the task, leave the environment, restructure the task, or restructure the environment.

In general, momentary discrepancies (Dm) are less important than set point discrepancies (Ds) or range discrepancies (Dr). To the extent that a momentary discrepancy is high, the environment is not well suited for a particular subpart of the task in question. To the extent that a setpoint or range discrepancy is high, the environment is not well suited for the overall task. The most problematic case is that of nonoverlapping ranges. If this occurs, the environment is totally unsuited for the task.

Implications of the Model

According to the model, environments must be articulated or matched with tasks. There are three ways of accomplishing this. First, the environment can be pre-engineered to meet the interpersonal contact requirements of the task. Second, the task can be structured to meet the potentials of the environment. Third, environments can be constructed in such a way as to provide users with a wide array of alternatives and options. Through interpersonal distancing mechanisms, the environment's users can behaviorally choose the level of contact that is the most appropriate for the task.

Given the constraints of spaceflight, this third option, that of making interior spaces definable and redefinable, offers certain advantages. First, in normal settings, where large interior spaces are possible and where there are few constraints against constructing numerous rooms of different sizes, it is possible to have task-dedicated areas. But in the case of the Space Station, areas will have to be multipurpose. To the extent that they are dedicated to the specific requirements of one type of activity, they may be inappropriate for another. Second, it is not always possible to forecast task requirements, especially if a task is unanticipated, novel, and/or needs to be performed under conditions of weightlessness or other unusual conditions. Flexible environments and the availability of interpersonal distancing mechanisms provide at least some insurance against

misestimates of task requirements. The key, then, is to provide Space Station occupants with an array of alternatives and options so that they can meet their needs for solitude, interaction with a limited number of other people, and open interaction with all other crewmembers. They require flexible environments and a full range of interpersonal distancing mechanisms.

It does not require large areas and a multitude of walls and doors to accommodate an array of interpersonal contact needs. The careful planning of "hard" architectural features (interior dimensions, walls, doors, etc.); the use of lightweight or "soft" features (screens, moveable partitions, and so forth); the availability of small personal items that can be used to stake out temporary territories; the creative use of decor variables such as color and light; and the recognition of possibilities in such areas as personnel selection, crew training, and social organization can fulfill a wide range of task requirements despite the Space Station's volumetric limitations.

RECOMMENDATIONS FOR SPACE STATION DESIGN

The recommendations based on the literature review and model fall into five categories. These are (1) Room and Furnishing Arrangements; (2) Maximization of Actual and Perceived Interior Space; (3) Creative Use of Filters, Blocks, and Illusory Barriers; (4) Distractors; and (5) Miscellaneous.

Room and Furnishing Arrangements

In the interests of flexibility, the Space Station should provide rooms of different sizes in order to offer opportunities for solitude, limited and protected communication, and open interaction (e.g. Helmreich et al. 1980; Stuster, 1984).

1. Private sleeping quarters are mandatory. They should include a pull-down desk for writing letters, keeping journals, and working on projects which require low levels of distraction. These private rooms should allow for control of heat, as much as possible, and also for the control of light without disturbing people in adjacent areas. Allowance should be made for "marking" or personalizing this area, even to the extent of mounting graphic materials on the walls (Helmreich et al., 1980; Oberg & Oberg, in press; Stuster, 1984).

2. Private sleeping quarters should be attached in such a way that two of them can be combined into a double unit to allow for private conversations, recreational activities, and so forth (Helmreich et al. 1980).

3. Screened "windows" between individual sleeping units would provide an alternative way of making an allowance for private conversations.

4. Personal possessions are seen as an extension of the self and are also useful for marking territories. Allowance should be made for the storage of personal possessions in private quarters (Helmreich et al. 1980; Stuster, 1984).

5. Entrances to opposing individual sleeping quarters should be staggered rather than perfectly aligned with one another; thus, when a person leaves his or her quarters the person in the opposite quarters will not feel "invaded."

6. The commander's room should be large enough for meetings of two or three people (Helmreich et al. 1980; Stuster, 1984).

7. Common areas should provide spaces which can be semiprivate, where someone could sit alone for reading, writing, or listening, or where two or three people could have semiprivate conversations (Helmreich et al. 1980).

8. Common areas should also make allowance for organized group activities. Eating is one example of such an activity. If shift work prevents eating at a common time, then holidays, birthdays, and other special occasions can be used to bring people together (Stuster, 1984).

9. Multiple hygenic facilities should be provided. These should be soundproofed, well ventilated, and located in convenient but inconspicuous areas (Stuster, 1984).

10. Work and living areas should be separated (Stuster, 1984).

11. Work stations should allow for either "back to back" or "front to front" orientations depending on such factors as the levels of concentration and information exchange required by the task.

12. Work stations should make allowance for the storage of personal, work-related items, especially if work stations must be shared.

13. Positioning devices (grab bars, restraints, "seats," and other anchors) should make it possible for astronauts to go about their business with a minimum of physically bumping into one another.

14. Positioning devices should encourage interaction on the same horizontal plane; that is, during a conversation, one person should not be forced to "look up" to the other.

15. Positioning devices should be relocatable.

Maximization of Actual and Perceived Space

The maximization of interior space increases the latitude for two people to vary their physical distances and angles of orientation towards each other and in this way regulate interpersonal contact. Additionally, environmental features which enhance perceived space tend to reduce feelings of crowding. Given the constraints placed upon the Space Station's dimensions, the maximization of interior space translates into incorporating design features which minimize nonoccupiable or "dead" space and contribute to an atmosphere of spaciousness.

16. The use of accordian or pocket doors prevents the loss of space required by a hinged door's arc.

17. Pull-down, pop-up and fold-out collapsible furnishings reduce clutter and provide extra space when not in use.

18. Increments in vertical space reduce needs for horizontal space (Cochran & Urbanczyk, 1982; Savinar, 1975).

19. Compared to relatively dark areas, relatively light areas appear less crowded (Mandel et al. 1980; Schiffenbauer et al. 1977) and promote less interpersonal distancing behavior under conditions where intimacy is seen as inappropriate. This suggests the use of relatively light colors for interior walls to reduce impressions of crowding.

20. Mirrors enhance perceived spaciousness.

Creative Use of Blocks, Filters, and Illusory Barriers

Blocks and filters refer to architectural and other features which eliminate, attenuate, or mask visual, auditory, olfactory, or tactile communication. Illusory barriers refer to design features that appear to set a person off from the rest of the group. The theme, once again, is to provide flexibility within the activity site so that the users can adjust interior areas to their changing needs.

21. Movable panels and screens, in different colors and sizes, may be used to expand and contract common work, recreational, and living spaces aboard the Space Station (Helmreich et. al. 1980).

22. Movable screens are useful for breaking up long corridors, thereby promoting an ability to regulate contact and reducing feelings of crowding.

23. Movable or rearrangeable furnishings encourage the psychological redefinition of areas to include greater or lesser numbers of people.

24. Personal possessions and other items can be used for staking out areas and encouraging other people to maintain distance (Sommer, 1969; Davis & Altman, 1976; Helmreich et al. 1980; Oberg & Oberg, in press).

25. Colors can be used for area demarcation (Helmreich et al. 1980).

26. Signs and other markers can help regulate social interaction (Helmreich et al. 1980).

27. Area lighting can help break-up large areas into public and semi-private areas.

28. Variable intensity illumination helps people to increase or decrease visual contact.

29. Dutch doors, interior windows, and comparable features help crewmembers vary the amount of contact that they have with people in adjacent rooms.

30. Background noise should not be completely eliminated. Some minimal level of continuous background noise would help minimize the distracting effects of talking and other intermittent noises.

31. Excellent ventilation and filtration systems and good hygienic and laundry facilities are essential to minimize offensive odors (Stuster, 1984).

32. Like body odors, personal litter and refuse can contribute to feelings of crowding. Orderliness and cleanliness can reduce feelings of crowding.

33. Crewmembers will need some place to get "off camera"; that is, escape the continuous surveillance of ground personnel. They should not have to retreat to the bathroom or their bedroom in order to accomplish this. Some areas either should not be under external surveillance, or should be under surveillance at the discretion of the areas' users (Helmreich et al. 1980; Stuster, 1984).

Distractors

Distractors are alternatives to intense social interaction. These design features increase the range of acceptable nonsocial behaviors.

34. Windows offer a useful alternative to social stimuli. By allowing one to divert one's attention away from companions, and by providing distal fixation points, windows can help reduce feelings of crowding on board. They may also reduce feelings of

distance from Earth, and serve other important psychological functions as well. Thus, there is a strong recommendation for multiple windows (Esser, 1984; Helmreich et al. 1980; Oberg & Oberg, in press).

35. Windows should be outfitted with blinds or shades not only to protect against harmful glare and radiation but also for varying access to the outside.

36. Pictures and graphic designs can provide useful diversions which help regulate the intensity of social contact (Baum & Davis, 1976; Helmreich et al. 1980). NASA pictures may serve an important symbolic function and reinforce mission values; pictures of Earth subjects may help reduce feelings of isolation from home. Complex stimuli can furthermore mitigate boredom. Such pictures could be printed on thin mylar "skins" and changed at frequent intervals.

37. Personal cassette recorders or other personal music systems provide an opportunity to auditorally tune other people out (Boeing, 1983b). Personal music systems offer advantages over group music systems, including the opportunity to control volume and content. Control over content allows people to enjoy selections which other people dislike and thus helps prevent programming conflicts.

38. Books, movies, and other recreational opportunities provide socially acceptable means for de-intensifying social contact (Boeing, 1983a; Stuster, 1984). Because movies are shown in a darkened room, they allow people to express emotions without visual exposure to others (Boeing, 1983b).

39. Recreational activities which require a specific number of participants provide the opportunity for those participants to have relatively high contact with one another while having relatively low contact with nonparticipants.

40. Personal diaries provide the opportunity for personal escape and for self-management (Oberg & Oberg, in press).

Miscellaneous

41. People who are aggressive, maladjusted, or have low self esteem have unusual personal space requirements (Altman, 1975; Cavallin & Houston, 1980). Thus, selecting out maladjusted people is likely to decrease personal space problems as well as offer other benefits.

42. People are more accepting of close confines when the group is characterized by harmonious relations than when it is characterized by conflict or hostility. Thus, selecting people who are compatible with one another and training the crew in

interpersonal relations may decrease some of the problems associated with crowding (Altman, 1973, 1975; Connors et al. 1985; Helmreich et al. 1980; Oberg & Oberg, in press; Stuster, 1984).

43. People adapt better to high-density conditions when these conditions are expected than when these conditions come as a surprise. It is thus essential to make sure that Space Station crewmembers have realistic expectations regarding the realities of the Space Station environment.

44. During crew training, steps should be taken to encourage the establishment of clear group norms regarding the usage of different areas, appropriate and inappropriate interpersonal distancing behaviors, and the need for individual crewmembers to withdraw from the group (McDonald & Oden, 1973; Stuster, 1984).

45. The scheduling of "alone time" removes the onus of temporarily retreating from the group (Stuster, 1984).

46. Inflight paging or intercom systems should make it possible to attract the attention of specific individuals without disturbing the rest of the crew.

47. Links with home may reduce feelings of loneliness and isolation from family and friends. According to Oberg and Oberg (in press), such links may be protected by the availability of houseplants and other Earth memorabilia, the availability of pictures and other personal momentos, and frequent news from home.

48. Astronauts should have access to two-way audio-video communications systems which are secure in the sense that they provide the opportunity for limited and protected communication with people of the astronauts' choosing (Connors et al. 1985; Helmreich et. al. 1980; Oberg & Oberg, in press).

49. Crew preparation should include training in the use of definable and redefinable environments and in the use of interpersonal distancing mechanisms.

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